Landscape pattern change in the upper valley of Min River

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Abstract: The upper valley of Min River (102°59′-104° 14′E, 31°26′- 33°16′N), which is consisted of the counties Wenchuan, Maoxian, Lixian, Heishui, and Songpan, refers to the part up to Dujiangyan City, and locates on the transition zone from the Tibetan Plateau to the Sichuan Basin. It is one of the most important forest areas in China, especially in Sichuan Province. Over past two decades, the landscape changed remarkably in the region. The 3S techniques (Remote Sensing (RS), Geographic Information System (GIS) and Global Position System (GPS)) were used to classify the images and analyze the landscape change. The remotely sensed data of Landsat TM 1986 and Landsat ETM+ 2000 were used to analyze the landscape change of the region. The landscape were classified into 10 types of cropland, forest, shrub land, economic forest, grassland, build up land, river, lake, swamp, and unused land. The results showed that: 1) the woodland and grassland were dominating landscape types in the upper valley of Min River, which is more than 91% of the study area; 2) the alteration of the landscape was mainly happened among forest, shrub land, grassland, economic forest, cropland, and build up land, where forest decreased from 51.17% to 47.56%; 3) the landscape fragmentation in the upper valley of Min River was aggravated from 1986 to 2000.
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Introduction

Landscape, as a geographical entity with obviously visual characteristics (Forman & Godron 1986; Forman 1995), is a major subject studied by both ecologists and geographers (Li 1999; Xiao 1999). It is formed with different patches of land and inlaid with different ecosystems (Xu *et al.* 2003). In landscape ecology, heterogeneity, visibility and physicality of landscape are emphasized (Xiao 1999). And the analysis of landscape spatial pattern is one of the centers of landscape ecology (Fu *et al.* 2001; Wang *et al.* 2003). The change of landscape pattern is the result of interaction between nature, biology and social elements (Turner & Lynn 1988). Not only the shape, size and type of patches but also the adjacency and spatial distribution of landscape pattern should be considered in the analysis of landscape pattern (Gustafson & Parker 1992; Chang *et al.* 1998). Therefore, how to find out the spatial distribution of landscape types in the complex mosaic of patches became one of the issues in the research of landscape pattern (Ma *et al.* 2000). At the same time, the change of landscape pattern has made a direct and indirect influence on the biotic and abiotic processes. But, the most important thing for us is to find, understand and use general principle of landscape change through short life process, to protect natural environment more effectively, and to keep ecology balance and a positive, healthy sustainable developing way (Zang *et al.* 2000). Hessburg *et al.* (2000) noted the importance of landscape pattern change at regional and subregional levels to aid in forest-level planning, watershed analysis, restoration conservation, and monitoring decisions. Only when we understand the characters of regional landscape, we could provide the scientific basis for the rational management and utilization of regional resources (Yue *et al.* 1997).

The technology of remote sensing (RS) is the best technological way to track timely or obtain spatial landscape information. Geographic information system (GIS) is the most effective technological means to carry out the spatial analysis of landscape (Xiu *et al.* 1999). Especially, the GIS overlaying change detection technique is quite effective for understanding landscape transformations (inter-conversions). Global position system (GPS) provides precise orientation information and helps for classification of satellite image.

The Min River is a first-order branch of the Yangtze River. It is about 735 km in length, 127.4 thousand km^2 in area, and with an altitude range of 3 570 m. The river is important not only in economy, but also in ecology for southwestern China (Ma *et al.* 2004). And it is the main water resource of the Sichuan Province, determining the production of agriculture and industry of the region. The upper valley of Min River refers to the part up to Dujiangyan City, which is the main water resource of the Aba canton, about 340 km in length, and 24.7 thousand km^2 in area. The four distinct characteristics in the study area were the complication of natural environment, the frangibility of ecosystem, the lag of economic development, and the transition of culture, respectively. Vegetation damage along the upper valley of Min River has taken place for at least a thousand years (Editorial Board of Sichuan Vegetation 1980; Zhang 1992). Forest cover has decreased from about 50% in the 1800s to about 18% at present (Editorial Board of Sichuan Vegetation 1980; Zhang 1992).

The objectives of this study are to analyze landscape changes in the upper valley of Min River during the past 15 years by satellite images interpretation, to provide the basis for future sustainable forest resource management and the suggestions for local development.

Study area

The upper valley of Min River (102°59′-104°14′ E,

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31°26′–33°16′ N) is located on the transition zone from the Tibetan Plateau to the Sichuan Basin, which including five counties of Wenchuan, Maoxian, Lixian, Heishui, and Songpan. It is 24 723.49 km^2 in area, with a high dissection, irregular topography, and topographically heterogeneous, supporting a varied flora and fauna because of special geography and climate conditions. The brown forest soils in the region are rich in lime (Bureau of Agriculture and Pasturage, Office of Soil Survey, Sichuan Province 1997). The mountainous topography results in a large degree of vertical variation in precipitation and air temperature. There are 1 500–2 000 sunshine hours per year. And annual precipitation is in range of 500–850 mm (Ma *et al.* 2003). Regional vegetation mainly consists of small-leaf arid shrubs (elev. 1 300–2 200 m), broad- and needle-leaf mixed forests and evergreen and deciduous broad-leaf mixed forests (elev. 2 000–2 800 m), *Picea* and *Abies* forests (elev. 2 800–3 600 m), and alpine shrubs and meadows (elev. >3 600 m) (Zhang 1992).

Methods

Landscape change was studied on the basis of remotely sensed data of Landsat TM 1986 and Landsat ETM 2000. Topographic map of 1:100 000 scale (1970) was also available for the study. The satellite images covering the study region were classified using a supervised classification method by ERDAS software. Before the interpretation of the satellite images, a landscape type reconnaissance was carried out in September 2003, by which a general understanding of the landscape situation in the study area was obtained. A reconnaissance survey of the study area was made to correlate the image characteristics and ground features by the standard technique of human-computer 'dialogue' interpretation. A field check was carried out in May 2004 to improve the accuracy of landscape map. Both interpreted maps were analyzed and managed by Arcview and Arc/info GIS software. On both maps, the smallest interpretable resolution was 30 m ×30 m.

In this paper landscape types within the study area were classified into (1) cropland, (2) forest, (3) shrub land, (4) economic forest, (5) grassland, (6) build up land, (7) river, (8) lake, (9) swamp, and (10) unused land.

Landscape metrics have been widely used to describe landscape patterns quantitatively with the quick development of geographical information system (GIS) in the past two decades. The different metrics differently responded to some of the pattern scenarios. So we must pay attention to the limitation, redundancy and real meaning of the metrics. Li *et al.* (2004) systemically discussed the ecological meaning, response against the pattern scenarios, and usage of the landscape metrics, and some landscape indices were recommended to use by authors. Based on these, area percentage and patch number (NP) per landscape type (Wang *et al.* 2003) were calculated using statistics to compare the landscape structure and landscape change during the two periods in this study.

Results

Landscape characteristics and structure

The patch number and area percentage of each landscape type for 1986 and 2000 in study area were shown in Table 1. In 1986, the forest took up more than 50% of the total study area, which constituting a continuous landscape matrix in the upper valley of Min River. The grassland was the second largest landscape type, which mainly distributed in the high elevation area. The third landscape type was the shrub land. The unused land and cropland ranked the fourth and the fifth, respectively. All the area percentages of the economic forest, build up land, river, lake, and swamp were less than 1%. All the woodland area occupied about 70% of the total area, and the area percentage sum of woodland and grassland was more than 91%.

Table 1. Patch number and percentage of each type in 1986 and 2000

Type	1986		2000	
	Patch number	Percentage	Patch number	Percentage
Cropland	1713	2.78	1786	2.98
Grassland	640	21.38	669	22.52
Build up land	221	0.03	225	0.04
Forest	1257	51.17	1229	47.56
Shrub land	1752	18.96	1936	21.02
Economic forest	177	0.48	231	0.67
River	3	0.77	3	0.77
Lake	116	0.04	118	0.04
Swamp	10	0.13	9	0.13
Unused land	186	4.25	176	4.26

The proportion of landscape types made a change from 1986 to 2000. Among all landscape types, it was only the forest area that decreased always. The forest was the only source of the increase of other landscape types, and these landscape types increased incoordinately except river, lake, and swamp. The order of landscape types in 2000 was the same as that in 1986. In 2000, the area of grassland and woodland was more than 91%, but less than that in 1986 appreciably. The common characteristics of the landscapes in 1986 and 2000 were that woodland and grassland were a continuous matrix, river the corridor, and the others landscape types the mosaic patches, which composed a typical patch-corridor-matrix landscape in the upper valley of Min River.

Landscape change between 1986 and 2000

The number of landscape types between 1986 and 2000 did not change, but the changes mainly happened among different landscape component types (Fig. 1).

The area of forest decreased about 4%, patch number of forest also decreased from 1 257 to 1 229 from 1986 to 2000. The transfer matrix showed that 9.78% of the forest took place change, 7.08% was converted to shrub land, and 1.63% changed into grassland. About 4.6% of shrub land was converted to grassland and 3.54% converted to forest. Among all landscape types, patch number of shrub land changed obviously and the increased area of which was the first too (Table 1). Though some shrub land was converted to other landscape types (Table 2), these did not change the increased trend of shrub land area.

The conversion rate between forest and shrub land was the highest, and followed by that between shrub land and grassland. The other conversion rates were all inferior to those of them. Patch number and percentage of grassland increased from 640 to 669 and about from 21.4% to 22.5% between 1986 and 2000, respectively (Table 1). The study results indicated that about 4.57% of shrub land and 1.63% of forest were converted to grassland, but about 2.1% of which changed into forest and 0.48% into shrub land at the same time (Table 2). Though there was some grassland converted to other landscape types, the area

of which always increased during this period.

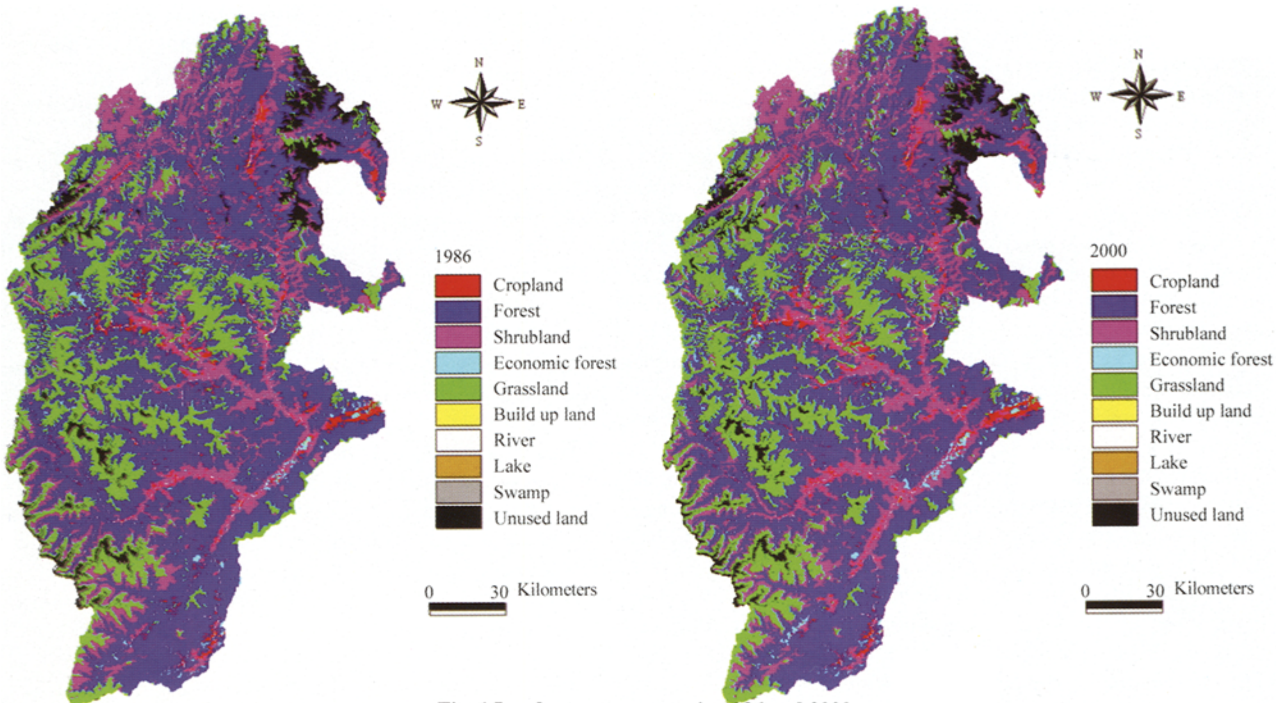

Fig. 1 Landscape type maps in 1986 and 2000

Table 2. Transfer matrix of each type from 1986 to 2000

1986	2000									
	Cropland	Grassland	Build up land	Forest	Shrub land	Economic forest	River	Lake	Swamp	Unused land
Cropland	-	0.38	0.22	1.65	3.54	0.67	0.02	0	0	0
Grassland	0.11	-	0.00	2.10	0.48	0.01	0	0	0	0.05
Build up land	0.43	0.19	-	0.08	0.19	0.03	0.03	0	0	0
Forest	0.33	1.63	0	-	7.08	0.29	0	0	0	0.05
Shrub land	0.95	4.57	0.01	3.54	-	0.37	0	0	0	0.06
Economic forest	1.58	0.01	0.03	0.93	6.43	-	0.01	0	0	0
River	0.03	0	0	0.06	0.06	0	-	0	0	0
Lake	0	0.37	0	0	0	0	0	-	0	0
Swamp	0	0	0	0	0.01	0	0	0	-	0.90
Unused land	0	0.34	0	0.46	0.14	0	0	0	0	-

The patch number of cropland was inferior to shrub land, taking up the second, and it increased between 1986 and 2000. Area and patch number of economic forest both increased. Because of little change in patch number and area, the other landscape types were not discussed in this paper.

Discussion and conclusion

In the study area, woodland coverage was the largest in history and declined before 2000. In early 1960s, there used to be four big departments of deforestation engineering (Chuanxi, Songpan, Heishui, and Maoergai) taking charge of deforestation in the upper valley of Min River until 1998, which caused the decrease of forest area quickly until early 1990s. During late 1950s and 1970s, forest area decline was accelerated due to wood harvesting during the "great leap forward" movement and the "cultural revolution". After the second land reform in 1982, the forest area did decrease too. This was not attributed to the land policy change, but the forest policy. Under the new policies of "Natural Forest Protection Program" and "retrieval of forest and grassland from agricultural land use", the decreasing trend of woodland took place change.

In the upper valley of Min River, a stockbreeding was main domain of local government. Some favourable politics were set down to develop a stockbreeding by the local government. And number and quality of grassland were a key factor for developing stockbreeding, so the increase of grassland area was rational. The cause of grassland change was the policies of local government.

The changes of cropland and economic forest were mainly related to land reform policy and market economy. The People's Commune happened in 1959, when the land of individual farmers was collected as common land of the community. All the land

was managed and used by the community based on state policy. This can be called the first land reform in the upper valley of Min River. At the end of 1978, the People's Commune was decided to resolve at the national level, and land-use rights were distributed to individual farmers again. This was called the "household responsibility system", namely the second land reform, and was completed in 1984 in China. But in the upper valley of Min River, this system was introduced in 1982. The idea of peasants was changed by the open and reform policy. They began to accept new things and technology. Some economic trees such as *Malus pumilaMicc*, *Zanthoxylum bungeanum* maxim, etc. were introduced and largely planted in the study area. From the middle of the 1980s, peasants started to plant cabbage. Because the cabbage was fertilized with muck and humus and very little farm chemical was used in the field at the same time, the price of which was more than that produced by the other regions, and it has become the main industry and the economic resource of peasants in the study area now. These evidences resulted in the cropland and economic forest area increased year after year.

Based on the comparison of different landscape type areas between 1986 and 2000, the major patterns of landscape change were gained in the upper valley of Min River. According to the above, the conclusions were as follows:

The landscape change was evident from 1986 to 2000 in the upper valley of Min River. Large number of forest was converted to shrub land and a number of shrub land changed into grassland. The changes mainly happened among forest, shrub land, grassland, cropland, economic forest, and build up land, and the other landscape types did not change. Only forest decreased always over past time. Summation of woodland and grassland areas was more than 90% of the total area. The upper valley of Min River was a typical patch-corridor-matrix landscape. During past time, the landscape in the upper Min River was fragmented year after year.

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